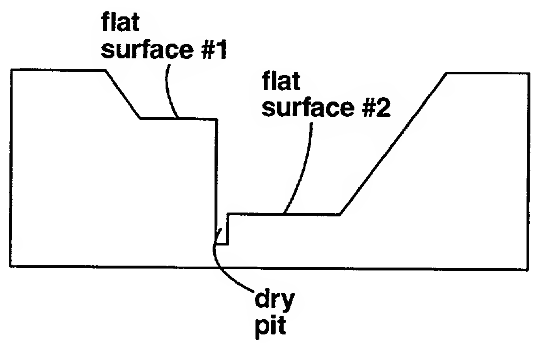
Inventors: Dan Steinberg, Jasean Rasnake

Structures made by Combined Etching

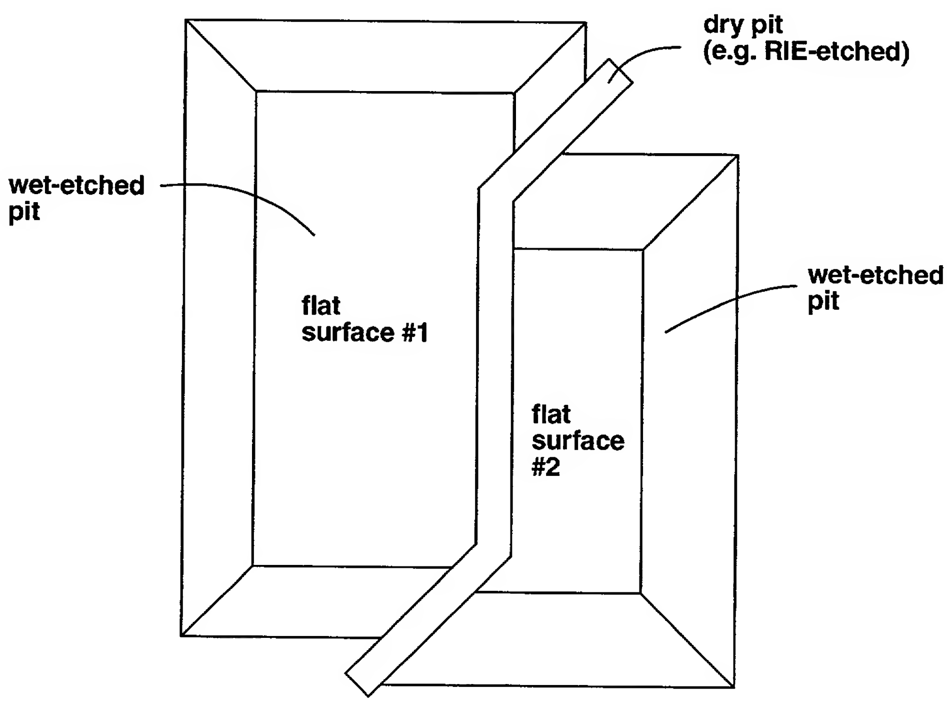
Methods for combining dry and wet etching were described in provisional patent application filed on Feb 7, 2001 by Dan Steinberg and Jasen Rasnake.

The present application decribes structures that can be made according to the methods described in the foregoing application.

For some applications, it is desirable to fabricate a structure having two flat, planar surfaces that are both parallel with the substrate surface. Below is a crossectional view of such a structure that can be made according to the present invention.

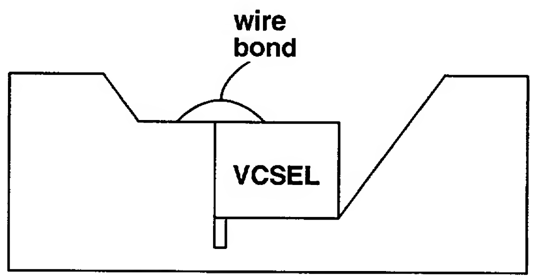


A top view of the structure is shown below. The flat surfaces are located at different depths. The flat surface #2 is deeper than flat surface #1.

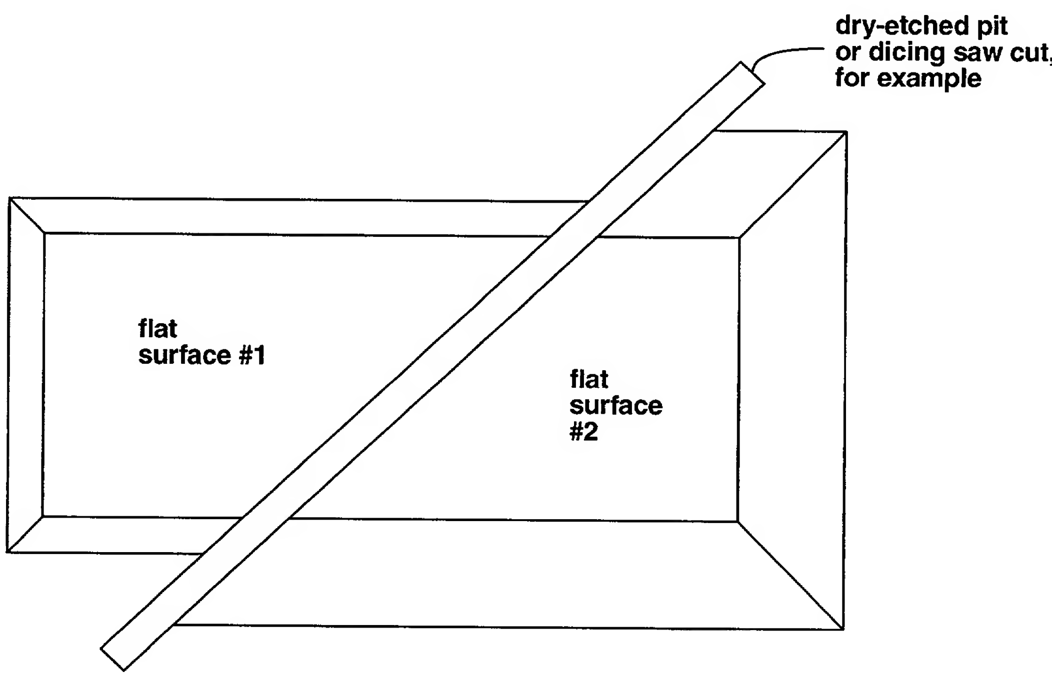


Of course, as described in the previous provisional application, the dry pit is etched before the wet pits. The ry pit is coated with a mask layer before the wet pits are etched.

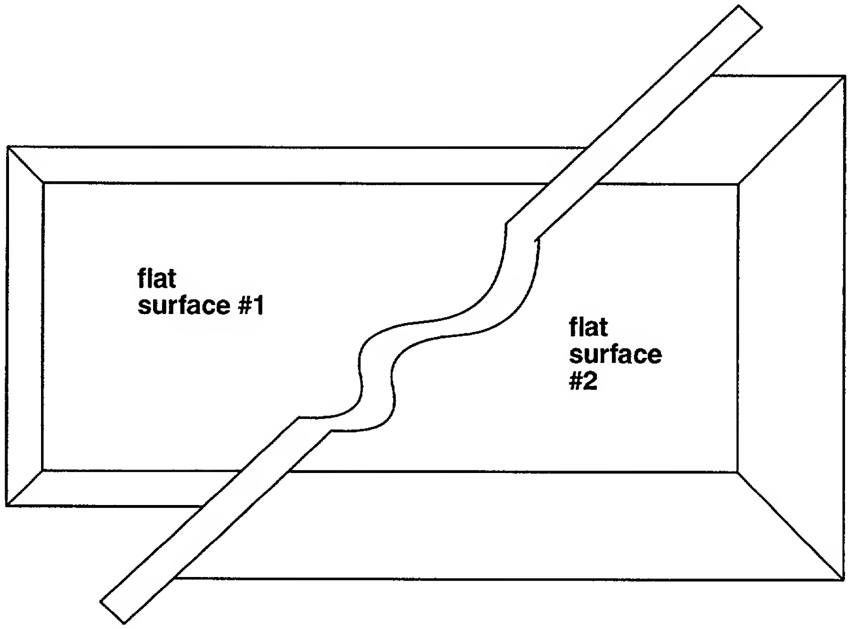
The present structure is particularly useful in an application where a VCSEL or photodetector is disposed on flat surface #2 9the deeper surface). This is because planar electrical connections (e.g. wire bonds) can be made between the flat surface #1 and the VCSEL. Planar eleectrical connections are desirable because they have better-characterized impedance characteristics than wire bonds that extend between two different levels.



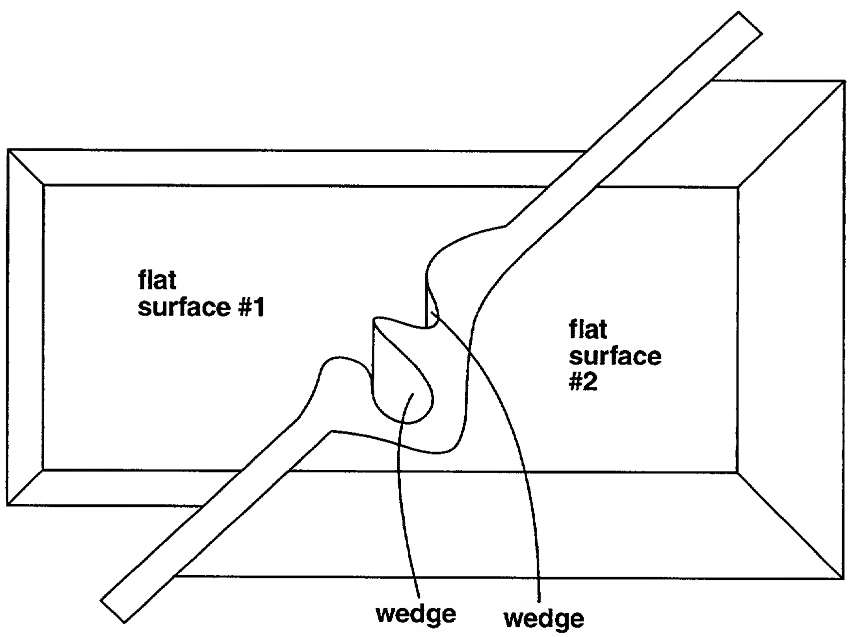
There are many different ways to shape the dry and wet pits so that the wet pits have flat surfaces at different depths. The dry pit can be a straight line, for example, as shown below.



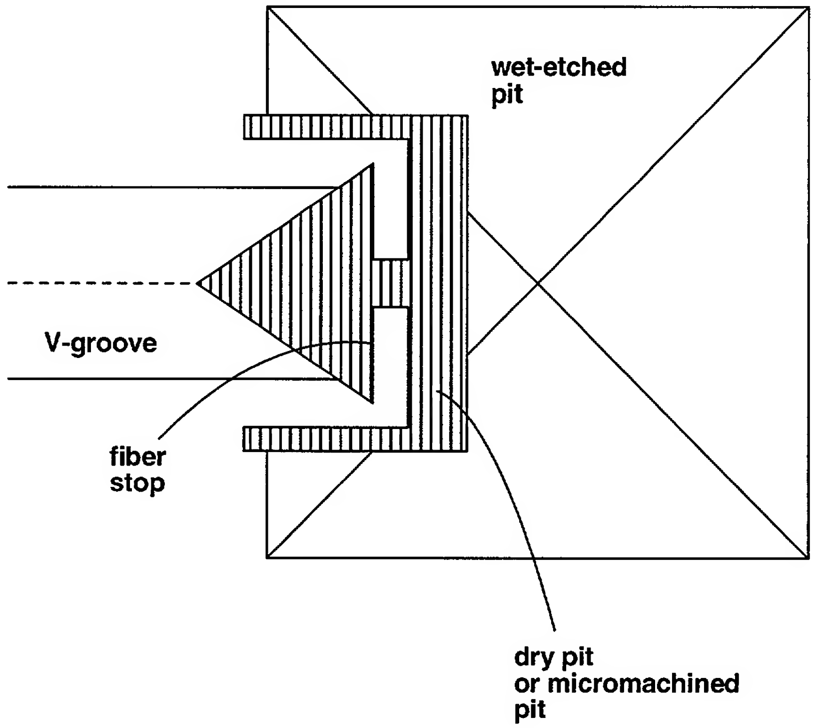
It is noted that the dry pit can be curved in the boundary length between the flat surfaces.



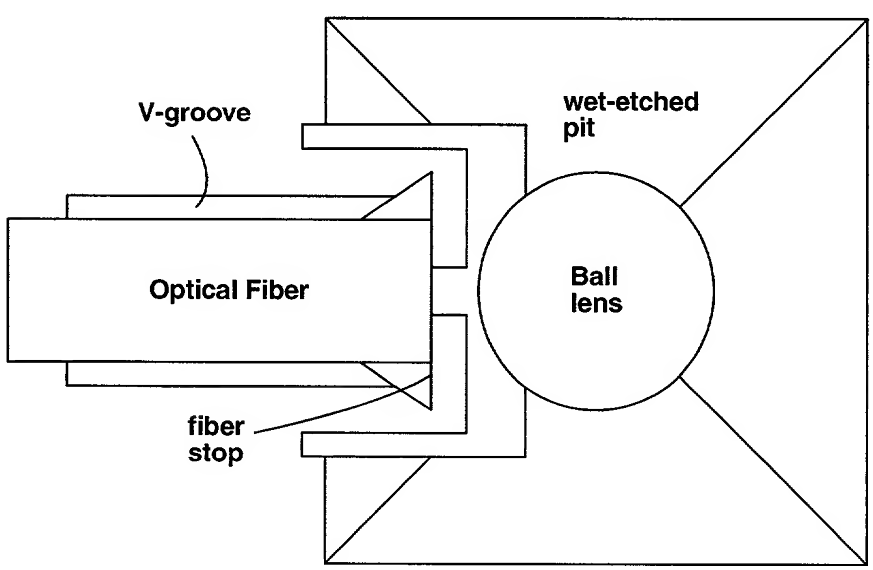
Small wedges may form, however, if the dry pit is too tighyl curved.



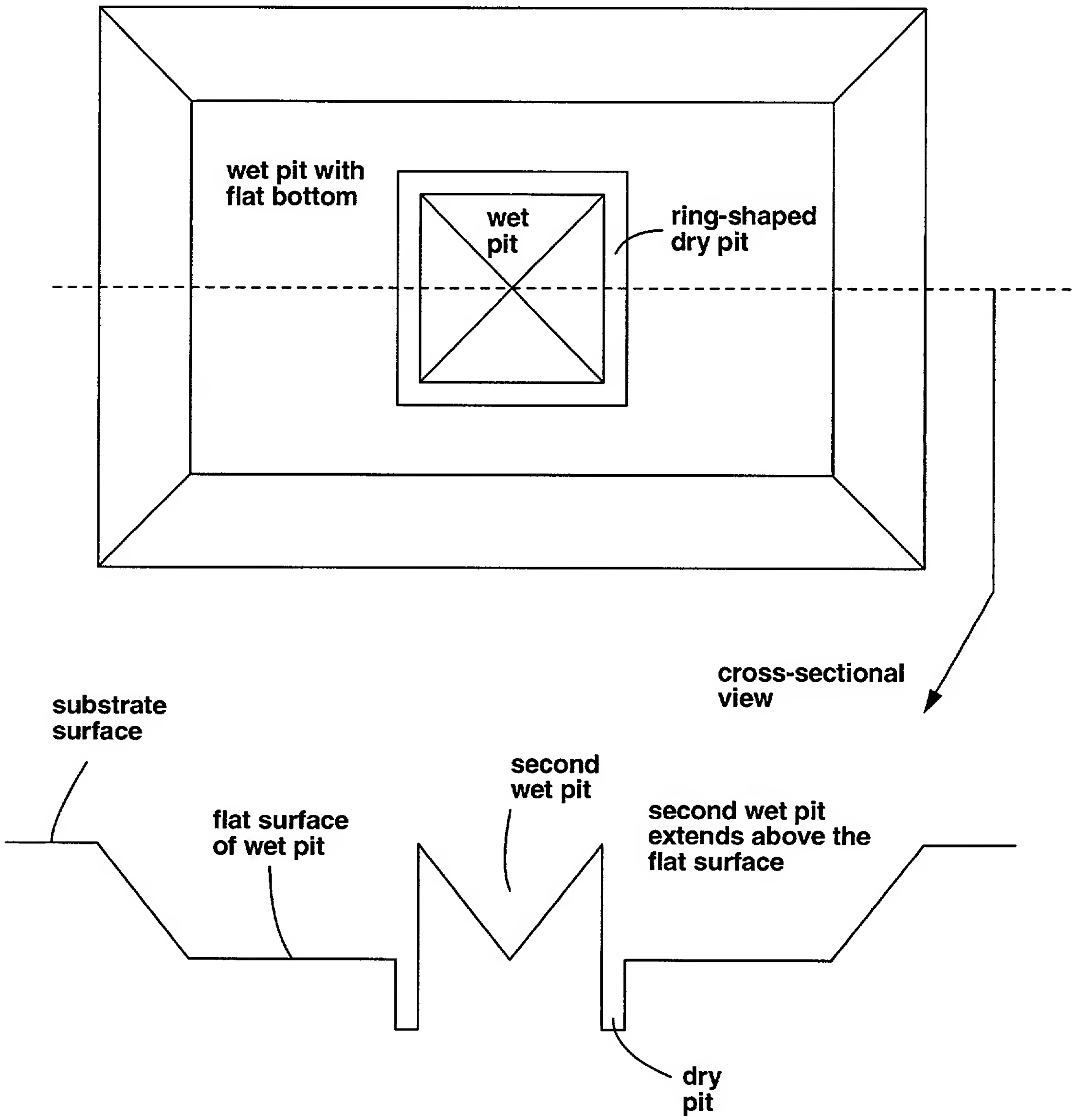
In another embodiment, a structure for coupling an optical fiber and a ball lens is provided. The structure has a V-groove with a fiber stop and a wet-etched pit for the bal lens. A top view is shown below.



Below is a top view of the device with an optical fiber and ball lens.

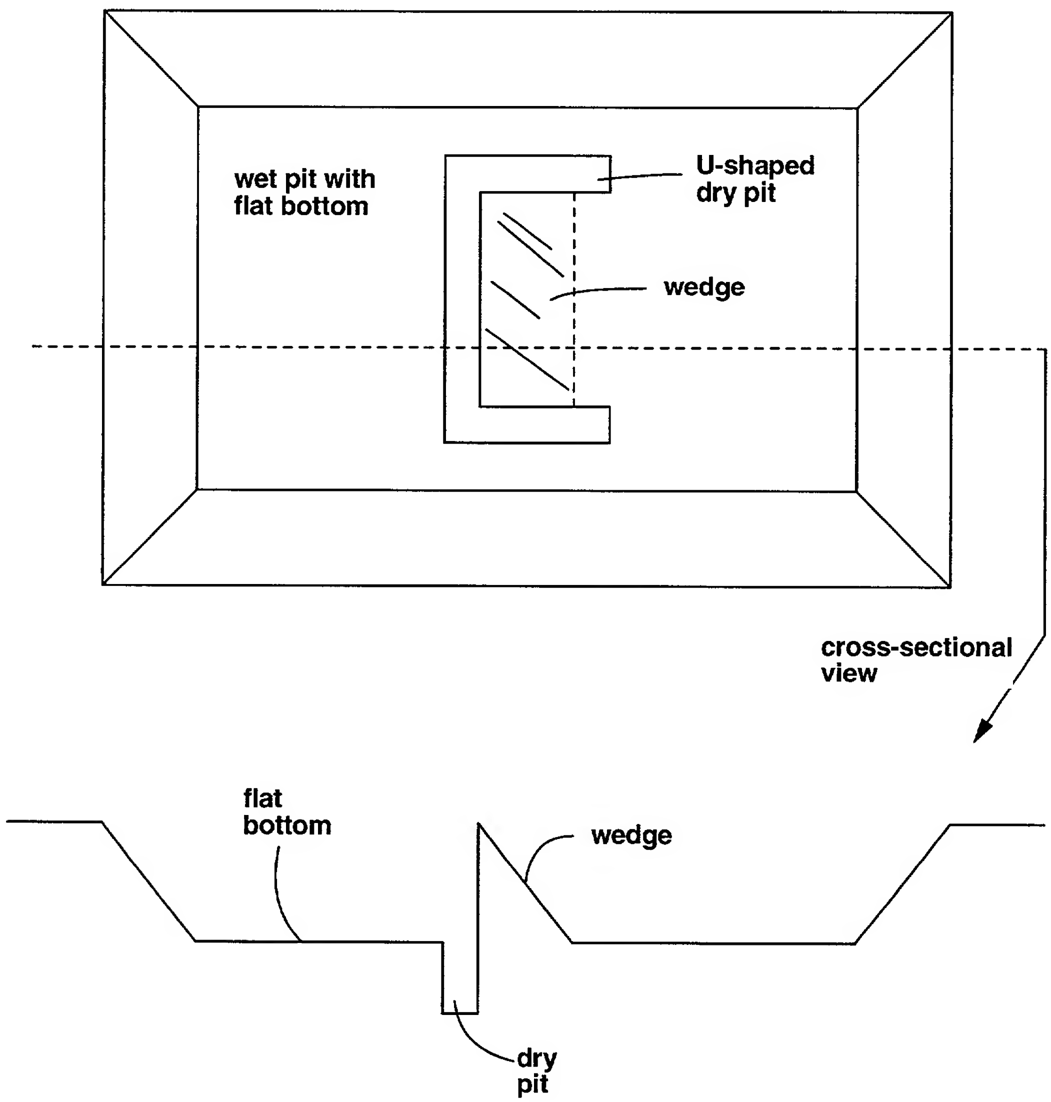


In another aspect of the present invention, a wet etched pit can be formed within another wet etched pit. The larger wet etched pit can have a flat bottom, for example. A top view of such a structure is shown below.

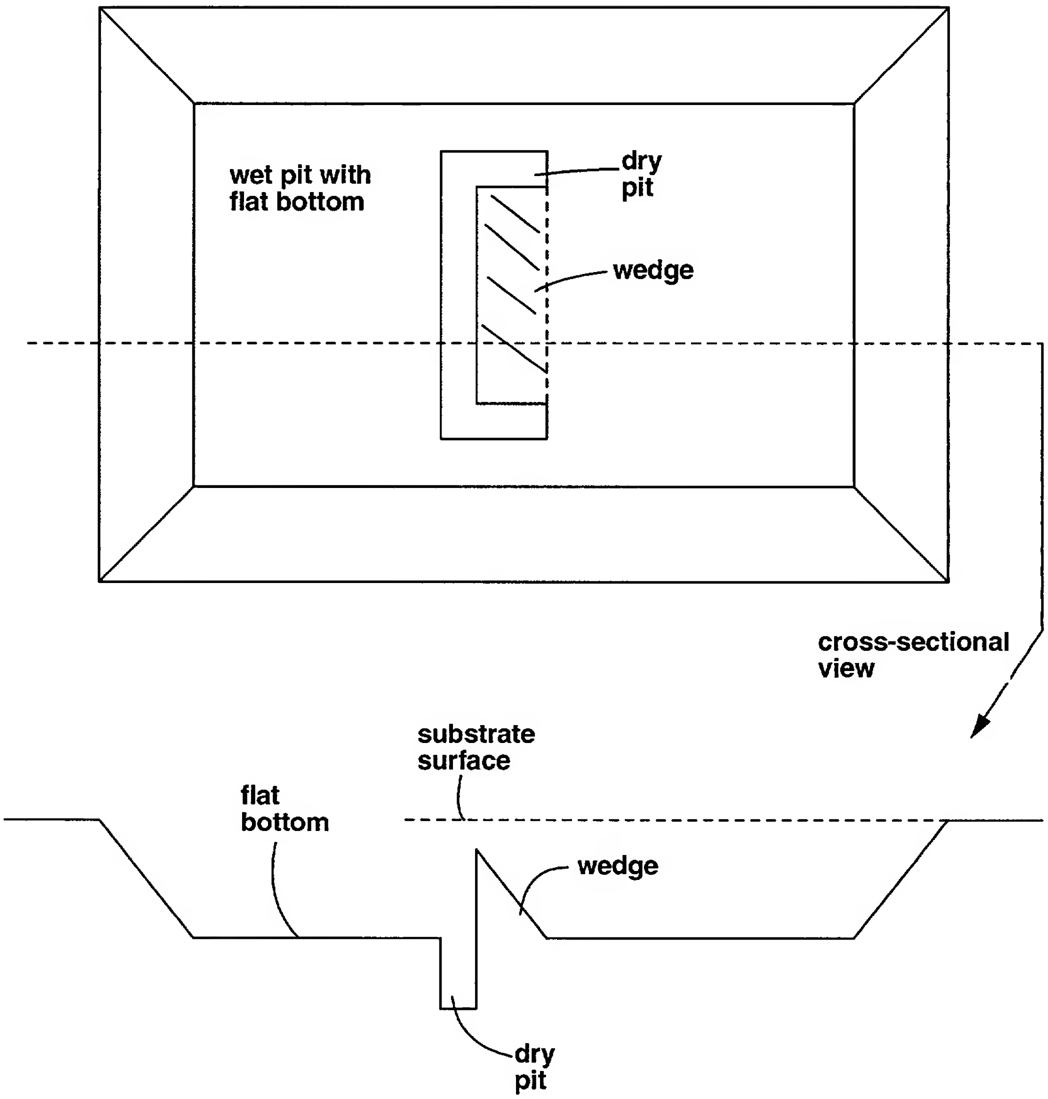


The structure described above can be used as a silicon optical bench. The central wet pit can hold a ball lens and the flat bottom can be used to hold optical devices such as switches or filters.

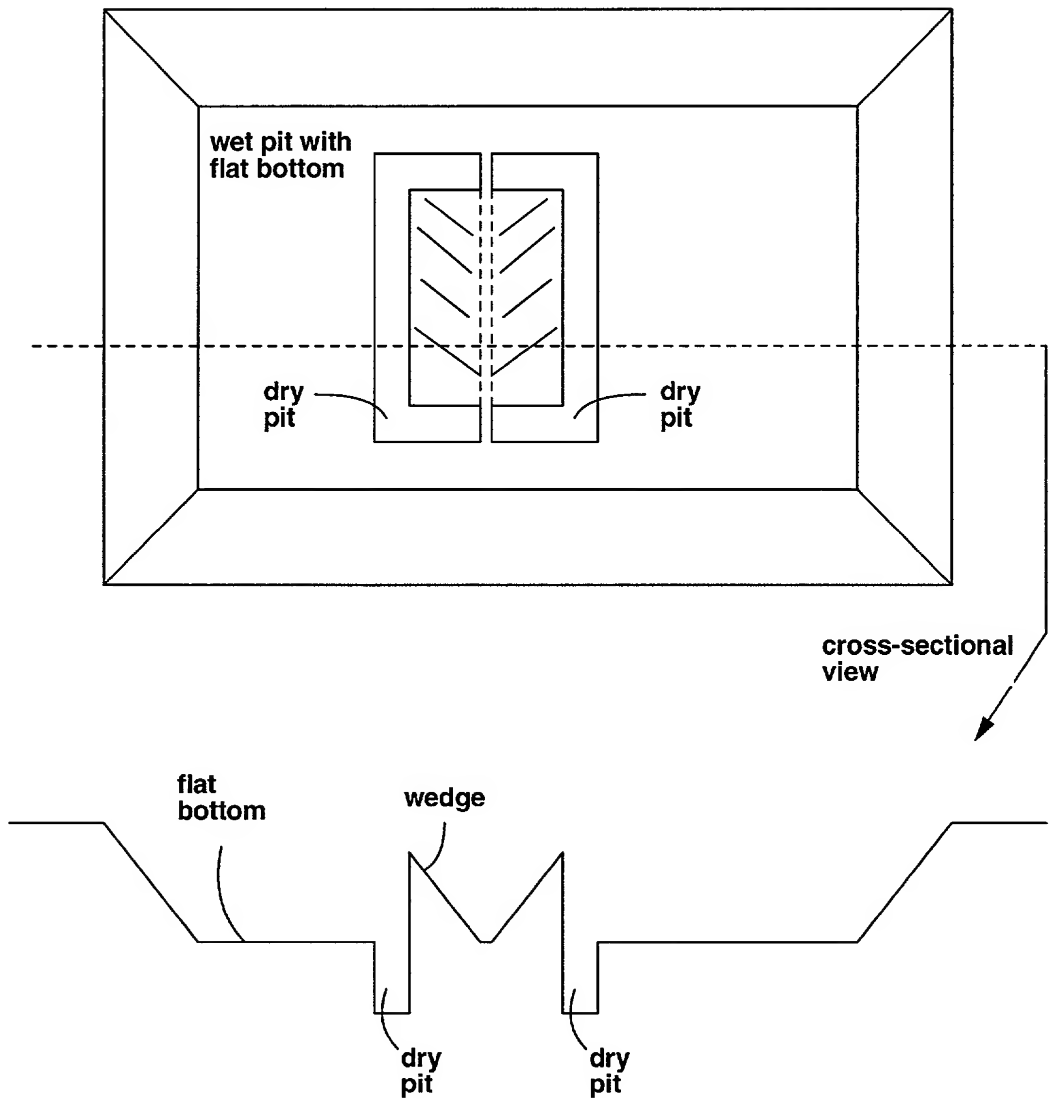
In another aspect of the present invention, wedges are formed on the flat bottom of a wet etched pit. In order to form a wedge, a U-shaped area is dry etched or machined, and coated with a hard mask according to the invention. A wedge in the bottom of a flat pit can function as a reflector, for example.



In another aspect of the invention, the U-shaped dry pit area is shaoed so that the size of the wedge is limited by the size of the U-shape. In this case, the top corner of the wedge will be below the substrate surface. This is apparent in the cross sectional view.



In another aspect of the invention, multiple U-shaped areas can be combined to form V-grooves or similar shapes in the flat-bottom pit.



Dry + Wet Technique for Making 2-D Fiber Arrays

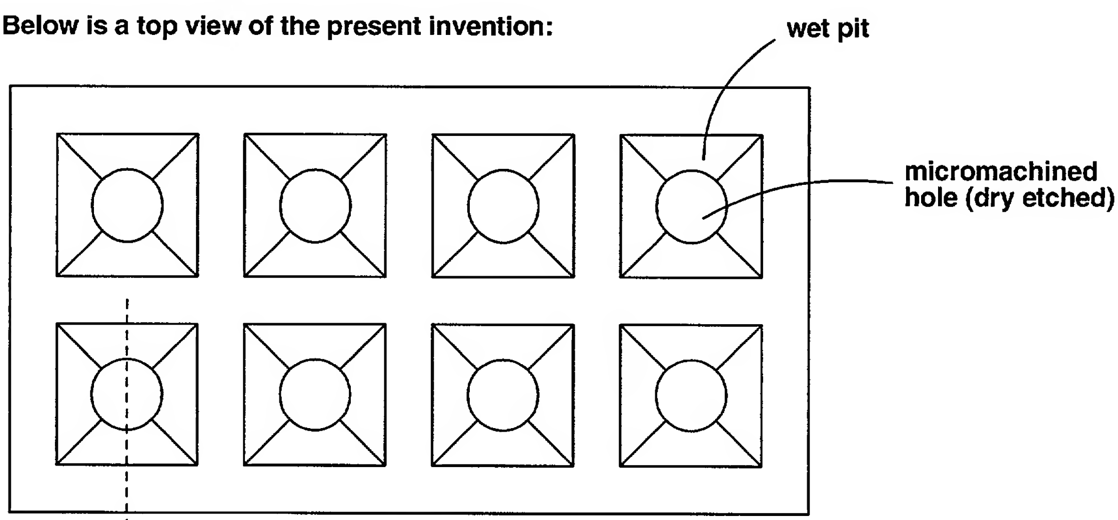
Inventors: David Sherrer, Dan Steinberg

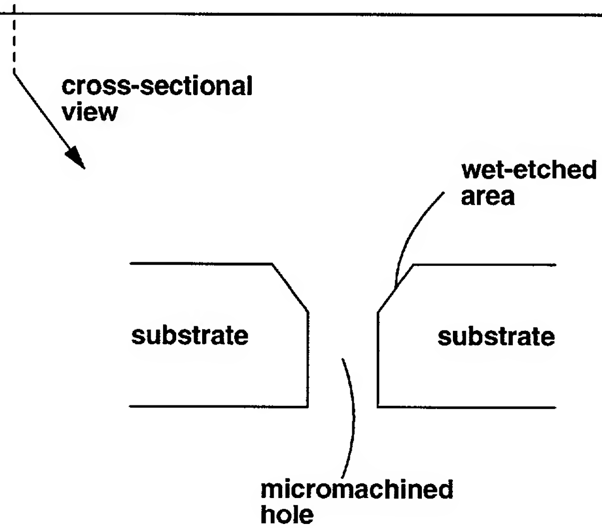
2-dimensional (2-D) fiber arrays are often made by etching or drilling holes in a flat substrate (e.g. silicon) and then inserting optical fibers into the holes. It can be difficult to insert the fibers into the holes because of the small sizes of the holes and fibers. Also, the holes are typically very close ly spaced.

The Present Invention

In the present invention, holes are drilled or etched or machined (e.g by reactive ion etching, ultrasonic drilling, laser drilling, laser machining, or electrodischarge machining) into the substrate. The holes are then coated with a hard mask material (e.g. SiO2 or Si nitride). Then, the wafer is wet-etched. The wet etching step can form a wet pit around each hole, or a V-groove along a row of holes. Methods for combined wet and dry etching are described in pending patent applications filed on feb 7 and feb 14, 2001.

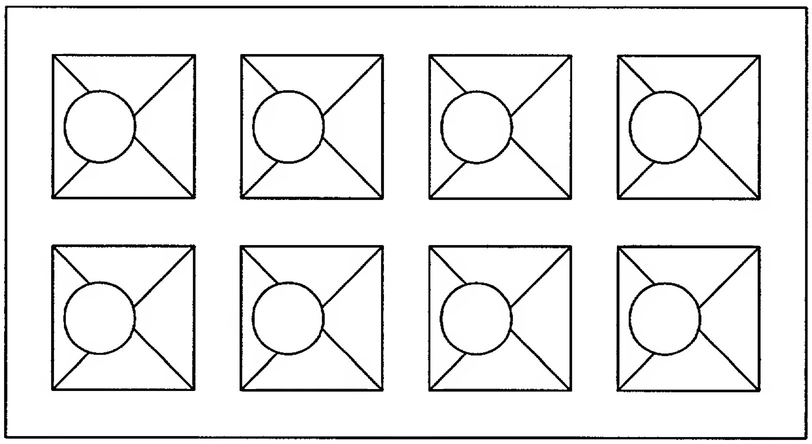
Below is a top view of the present invention:



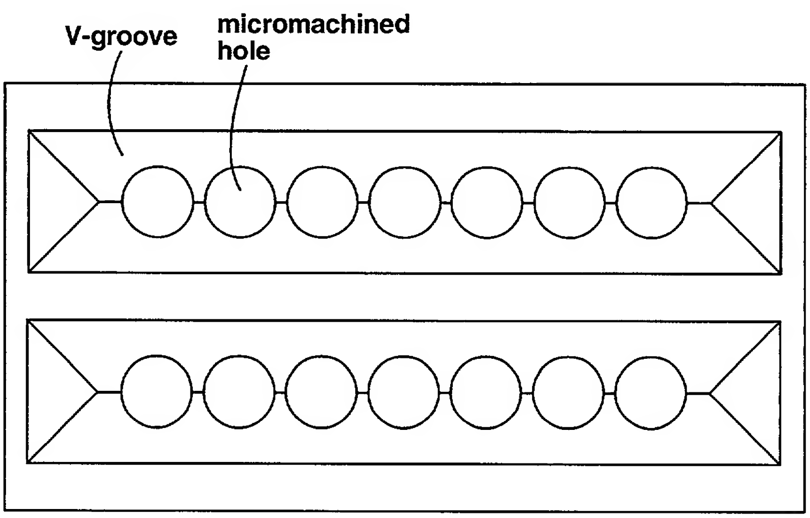


The wet pit associated with each hole acts as a funnel for guiding an optical fiber into the hole. In this way, the assembly process is simplified.

It is noted that the holes can be located off-center within each wet pit. This is illustrated below. Having off-center holes can be useful for locating the fibers in cases where the fibers are guided into the holes from one direction (e.g. from the right side in the figure below).



In another aspect of the present invention, the holes are located within a V-groove. The v-groove provides passive alignment in one direction when aligning the optical fibers with the holes.



What is claimed is:

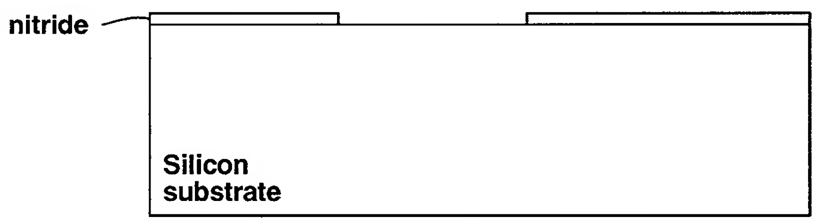
1) A substrate having a micromachined hols disposed within a wet etched pit of V-groove.

2) A 2-D fiber array having fibers disposed in micromachined holes surrounded by wet-etched pits or V-grooves.

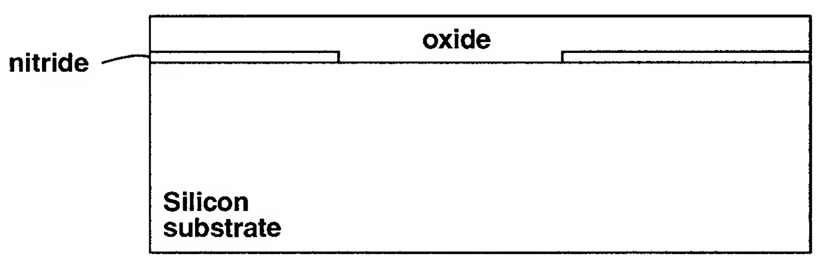
The present invention includes another method for making the chips. In this method, dry etching is not necessarily used. Dry etching is replaced by ultrasonic drilling, laser etching, sawing, electrochemical etching or similar material removal techniques. Below is an explanation of the present method using these techniques.

Method #1:

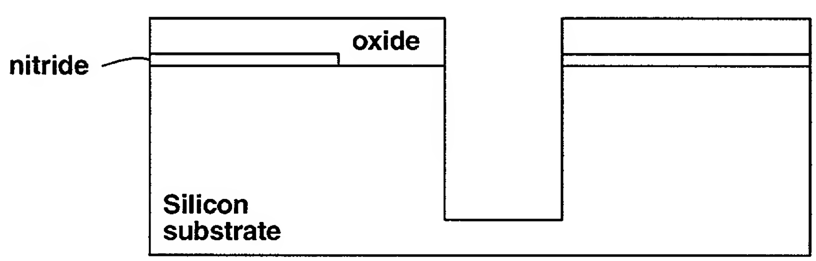
1) Deposit and pattern a hard mask layer (e.g. nitride). The nitride layer does not cover areas to be wetetched. The nitride area may partially cover areas to be machined (i.e., ultrasonically drilled, electrochemically etched, sawed etc), provided that the machining process can remove the nitride or hard mask material.



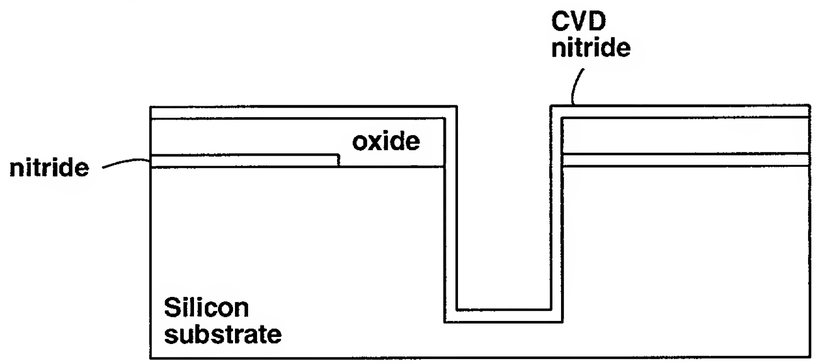
2) Coat the wafer with CVD oxide, PSG, or BPSG.



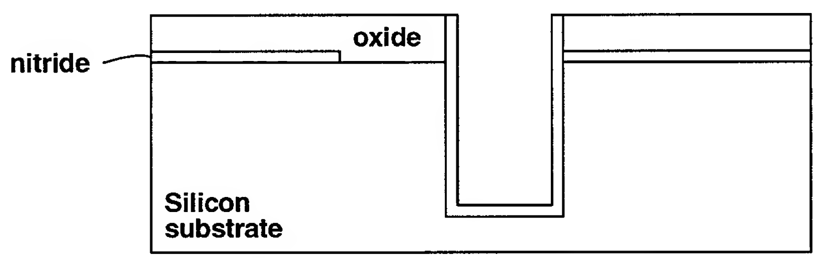
3) Perform the machining process on the silicon. The machining process can be any process that removes substrate material. The machining process should be able to cut through the nitride and oxide layers.



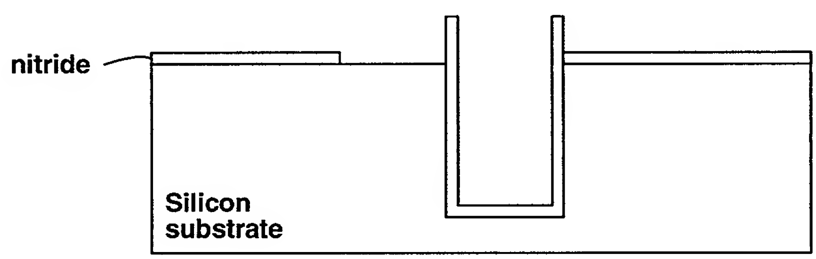
4) Coat the wafer with CVD nitride.



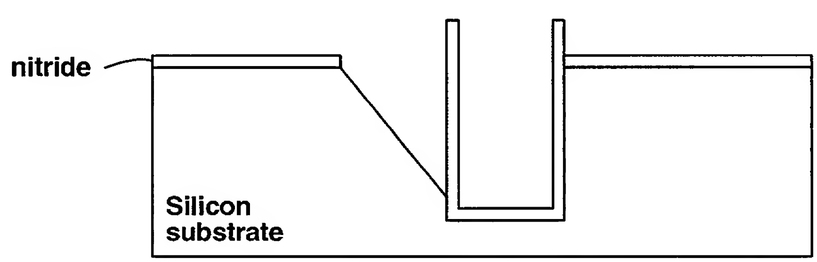
5) Planarize to remove the nitride from the top surface.



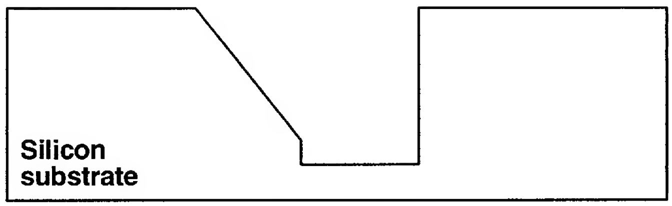
6) Remove the oxide. This can be done by a dilute HF etch.



7) Wet etch the substrate.

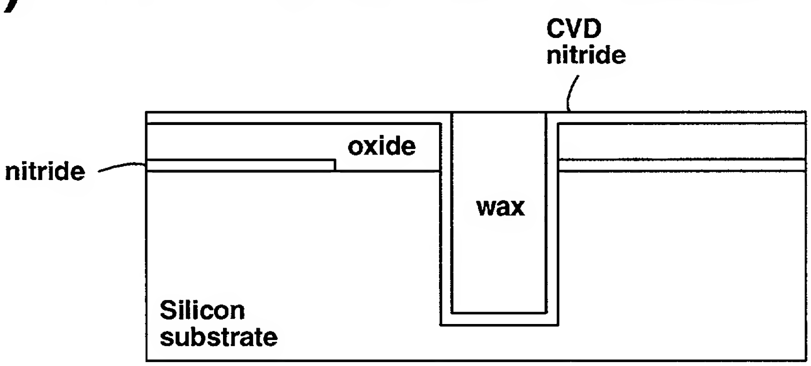


8) Remove the nitride.

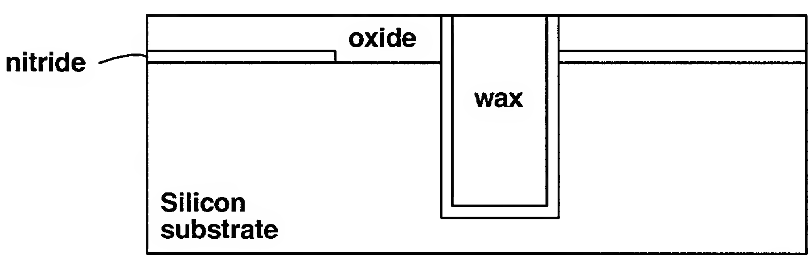


Alternatively, after step (4), the wafer can be filled with a figutive mask material that resists nitride etches (e.g. wax). In this case, the method proceeds as shown below.

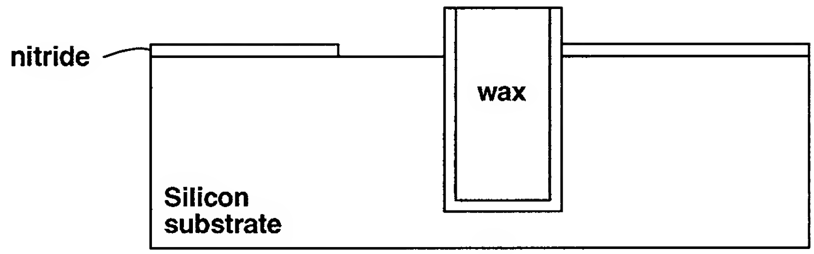
5b) Fill the pit with a fugitive mask material such as wax, polymer or photoresist.



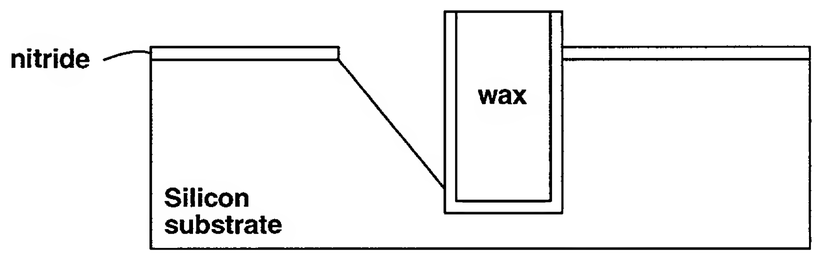
6b) Etch the nitride layer.



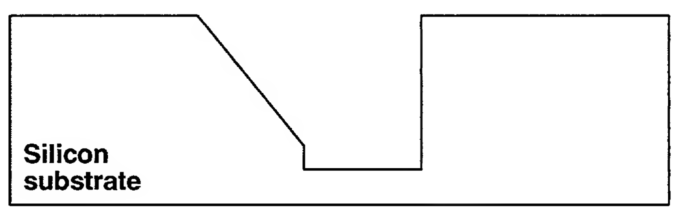
7b) Etch the oxide layer.



8b) Wet etch the substrate.



9b) Remove the wax and nitride.



What is claimed is:

1) Micromachined structures substantially as shown and described.

2) Methods for making micromachined structures as shown and described.

3) A micromachined chips with two joined, flat-bottom pits.

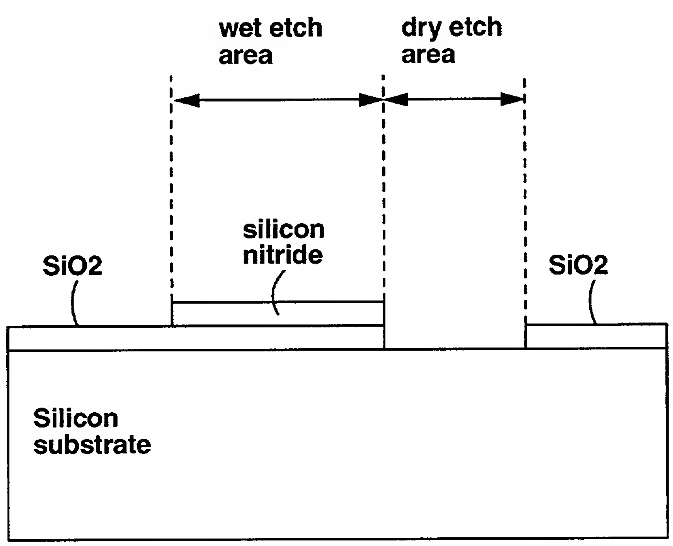
4) A pit or wedge disposed in a flat-bottom pit.

Combined wet and dry etching can be performed according to a number of different methods. The dry pit can be coated with CVD nitride or oxide, or can be thermally oxidized. The present invention can be used with silicon or other materials (e.g. GaAs) that can be dry etched wet etched (isotropic or anisotropic) and can be conformally coated with a mask material.

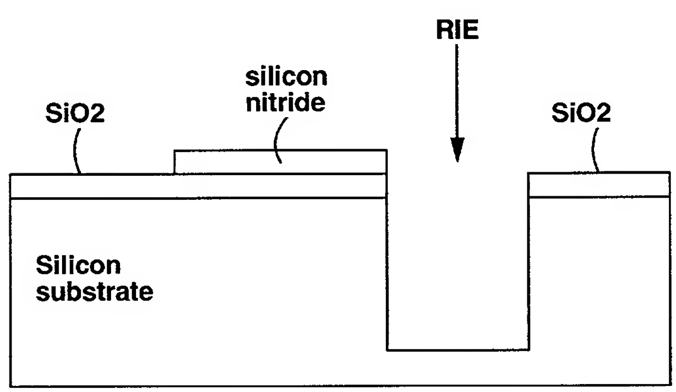
Below is a first embodiment for making the structures of the present invention:

Method #2

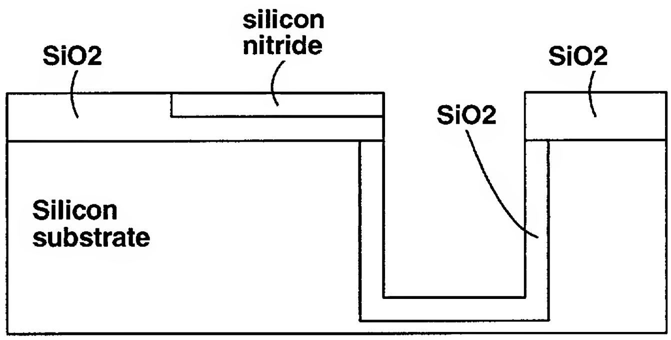
1) Start with a silcon substrate. Deposit and pattern an SiO2 layer and a nitride layer. The SiO2 layer should be thck enough to serve as a mask during the dry etch step. (e.g. the SiO2 layer can be about 2 microns thick for a 100 micron deep dry pit. The patterns in the oxide and nitride determine the wet and dry etch areas as shown.



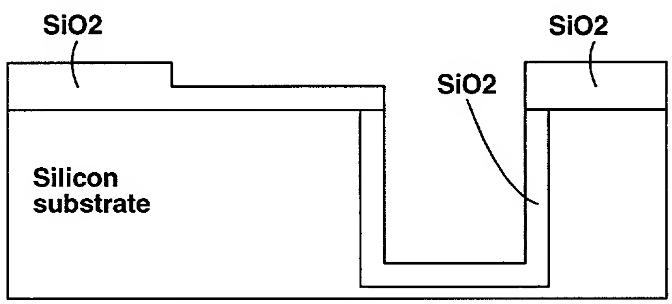
2) The dry pit is formed. The dry pit can be performed by reactive ion etching, plasma etching, ion milling or any other directional process.



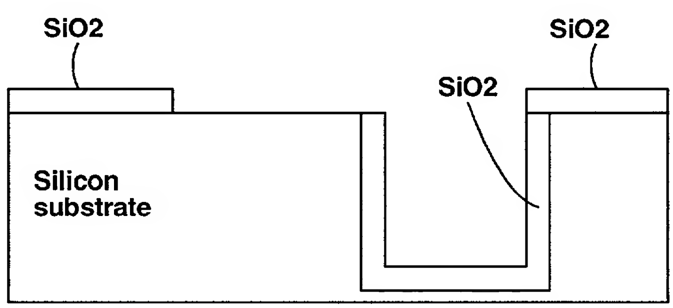
3) The wafer is thermally oxidlzed. The sidewalls are necessarily oxidized in this step. The thermal oxidations tep causes the oxide layer to thicken in areas outside of the nitride.



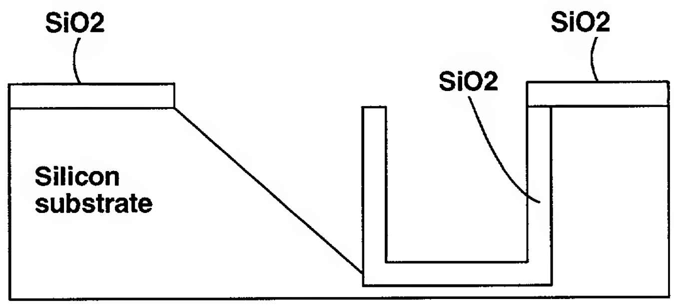
4) The nitride is removed. This can be done with a wet etch.



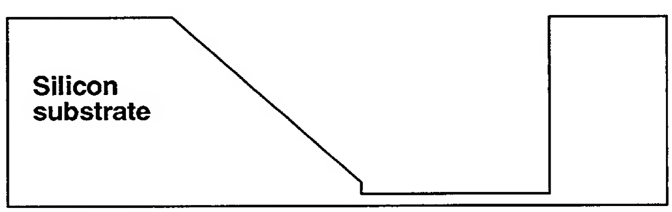
5) A short duration oxide etch (wet or dry) removes the oxide that was under the nitride. Other oxide areas remain intact because they are thicker.



6) The wafer is exposed to an anisotropc wet etch. KOH should not be used because it will attack the oxide. EDP or TMAH can be used because they will not attack the oxide as strongly.

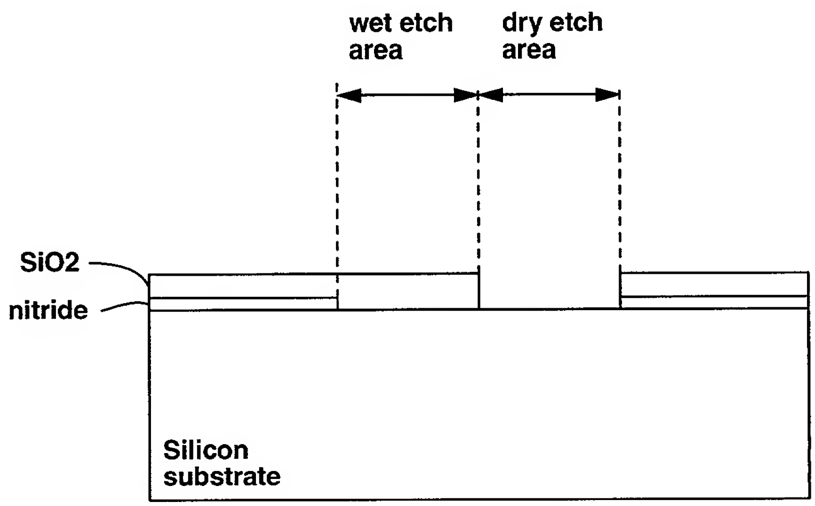


7) Optionally, the oxide mask material is removed. This can be done in a dilute HF etch.

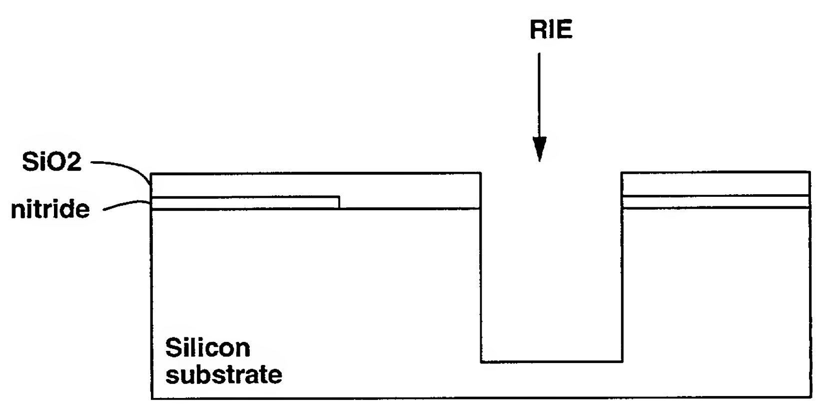


Method #3

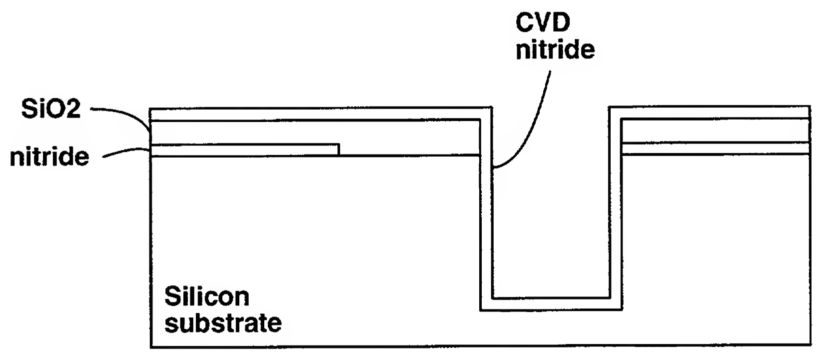
1) Deposit/pattern nitride layer, and then deposit/pattern oxide layer. The oxide layer can be thicker than the nitride layer. the oxide layer can comprise PSG or BPSG, for example. The nitride and oxide patterns determine the wet and dry etch areas as shown.



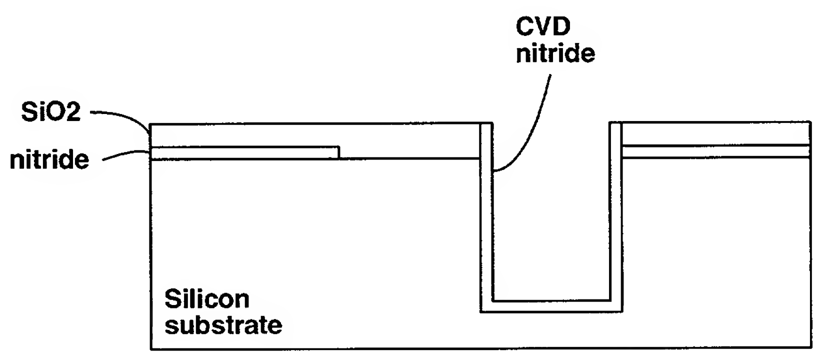
2) Etch the dry pit. This can be done with RIE, ion milling or similar processes.



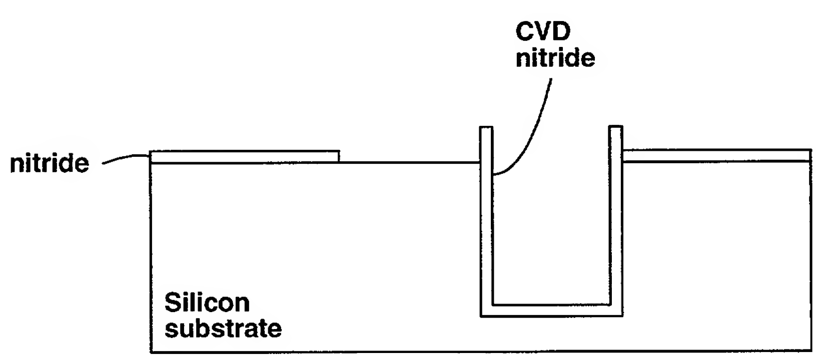
3) Conformally coat the wafer with CVD nitride. The dry pit is coated with nitride.



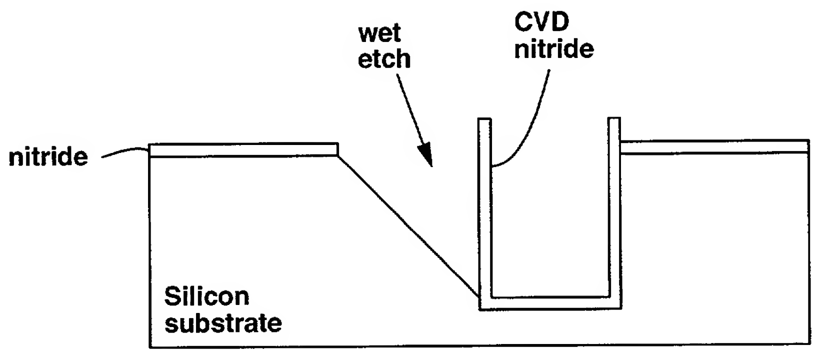
4) Planarize or polish the wafe so that nitride is removed from the top surface only.



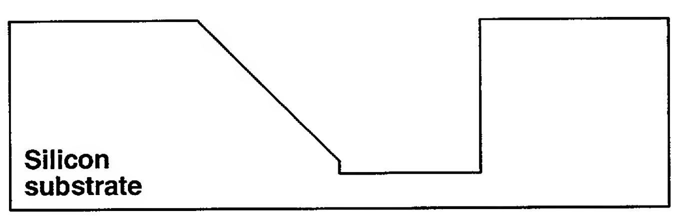
5) Remove the oxide. This can be done with dilute HF.



6) Wet etch the exposed areas. This can be done with KOH since the mask is made of nitride.



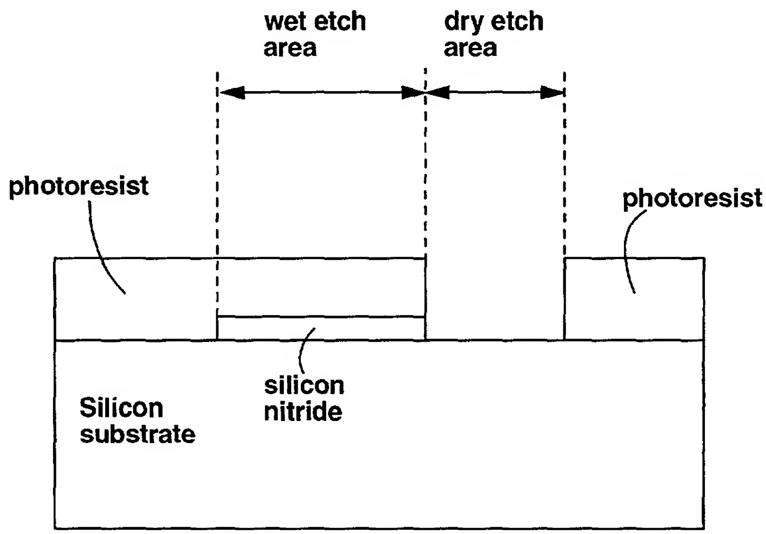
7) Optionally, the nitride material is removed with etchant that does not damage the silicon.



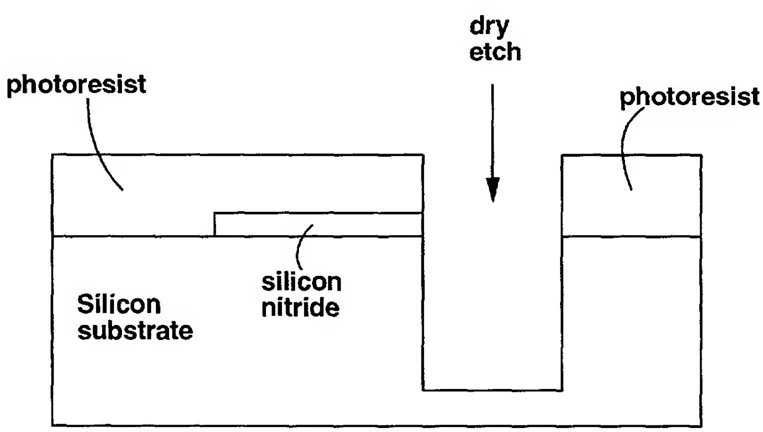
Below is a third methof for making the structures of the present invention.

Method #4

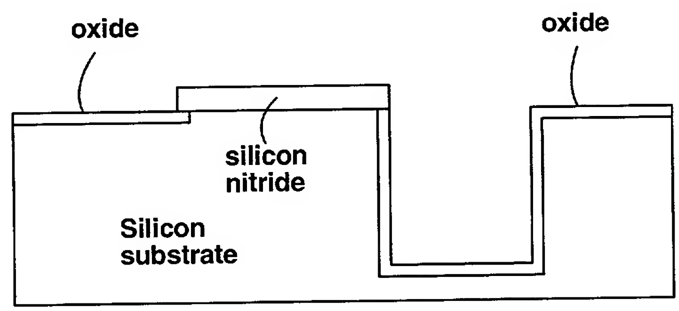
1) Deposit and pattern a hard mask material that blocks oxide formation (e.g. silicon bitride), and then deposit and pattern photoresist. The dry and wet etch areas are defined as shown. The photoresist does not need to cover the entire hard mask area.



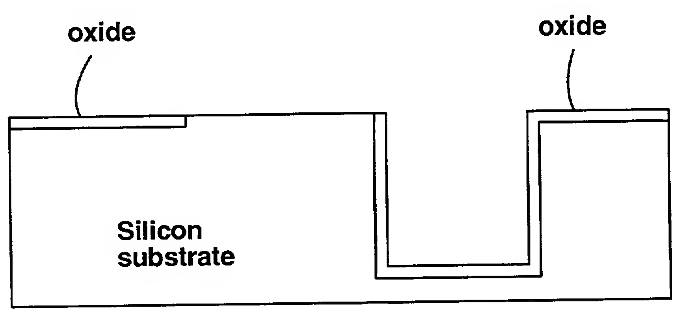
2) Dry etch the area exposed by the photoresist and hard mask.



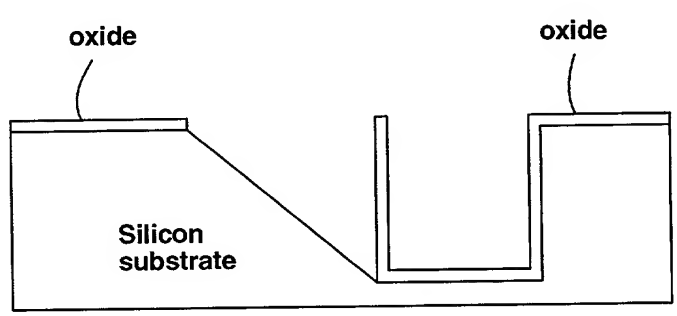
3) Remove photoresist and oxidize. Oxide will not grow under the hard mask.



4) Remove the hard mask.



5) Wet etch with anisotropic etchant.



The oxide can be removed after step (5).